In this issue

Climate change and India: Emissions, mitigation, impacts and adaptation

Climate change is among the most important global environmental challenges facing humanity with implications for food production, natural ecosystems, freshwater supply, health, etc. The Third Assessment Report of the IPCC (Intergovernmental Panel on Climate Change) has shown that the earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era. According to a survey conducted for United Nations Environmental Programme, environmental experts and research scientists perceive climate change as a dominant environmental issue. This survey, covering over 50 countries, found that 51% of scientists considered climate change as the major environmental problem facing humanity, compared to 29% freshwater scarcity, 28% deforestation and desertification, 28% freshwater pollution, 23% loss of biodiversity, etc. UNFCCC (United Nations Framework Convention on Climate Change) was born out of the scientific evidence that first concerned the scientific community followed by the global citizens and institutionalized by global policy makers through the UNFCCC. The Kyoto Protocol to the UNFCCC laid out guidelines and rules regarding the extent to which industrialized countries should reduce their GHG emissions, as well as mechanisms and instruments to promote adoption of climate-friendly mitigation technologies and to assist in adaptation to the adverse impacts of climate change. Though the proposed reduction of GHGs under the Kyoto Protocol is a positive first step, the commitments therein remain far from the mitigation needs to achieve stabilization of the concentrations of GHGs that could prevent the dangerous impacts from anthropogenic interference with the climate (Sathaye *et al.*, **page 314**).

Though there are uncertainties with respect to projections of climate change into 2100 and beyond, most Global Circulation Models (GCMs) are robust in predicting global warming. The GCMs are not robust in projecting changes, increases and decreases in regional rainfall. India, though not a dominant contributor to global GHG emissions, would be adversely impacted by the projected climate change due to significant dependence of the population and economy on climate-sensitive sectors such as agriculture, forests, fisheries and coastal zones. India therefore has a high stake in scientific advancement and global negotiations for addressing the problem of climate change.

Thus, there is a need for a significant boost for scientific literature on all aspects of climate change, namely delineation of GHG emissions pathways from India, projections of regional climate change, assessment of impacts of climate change on natural ecosystems and socio-economic systems (such as food production or coastal settlements), mitigation and adaptation measures to address climate change and estimation of their costs. Reliable scientific and economic studies and information is required at national and regional level within India to assist policy makers, industry and climate-sensitive sectors and communities to mitigate and adapt to climate change. The special section in this issue is an attempt to present the latest findings of a network of studies conducted by several leading scientific institutions and researchers.

Sathaye *et al*. (**page 314**) suggest that historically, the responsibility for rising greenhouse gas concentrations lies largely with the industrialized world, though the developing countries would have increasing share in future emissions. The projected climate change under a range of scenarios shows high likelihood of adverse impacts, which would be especially severe on developing countries due to low adaptive capacity of communities and productive sectors. The present level of efforts under the UNFCCC, including the Kyoto Protocol provisions, remains inadequate to address the climate change challenge. The most effective way to address climate change would be to align national development actions along a sustainable development pathway by shifting to environmentally sustainable technologies and enhancing capabilities of communities. The immediate issue of importance to developing countries like India is reducing the vulnerability of their natural and socio-economic systems to the projected climate change.

Sharma *et al*. (**page 326**) have presented the improvements made in the GHG inventory estimation reported in the National Communication with respect to the earlier published estimates and highlights the strengths, the gaps that still exist and the future challenges for inventory refinement. An assessment of the current and projected trends of GHG emission from India and some selected countries indicates that though Indian emissions grew at the rate of 4 per cent per annum during 1990–2000 period and are projected to grow further to meet the national developmental needs, the absolute level of GHG emissions in 2020 will still be below 5 per cent of global emissions and the per capita emissions will still be low compared to most of the developed countries as well as the global average.

Findings of regional climate modelling system, PRECIS (Providing Regional Climates for Impacts Studies) developed by the Hadley Centre, applied for India are presented by Rupakumar *et al*. (**page 334**) The present-day simulation (1961–1990) with PRECIS is evaluated, including an examination of the impact of enhanced resolution and an identification of biases. The Regional Climate Model is able to resolve features on finer scales than those resolved by the GCM, particularly those related to improved resolution of the topography. PRECIS simulations under scenarios of increasing greenhouse gas concentrations and sulphate aerosols indicate marked increase in both rainfall and temperature towards the end of the 21st century.

Gosain *et al.* (**page 346**) have attempted to quantify the impact of the climate change on the water resources of Indian river systems. The study uses the HadRM2 daily weather data to determine the spatial–temporal water availability in the river systems. The initial analysis has revealed that under the GHG scenario, severity of droughts and intensity of floods in various parts of India are projected to increase. This paper presents the detailed analyses of two river basins predicted to be worst affected; Krishna river basin with respect to drought and Mahanadi river basin by floods.

Ravindranath *et al*. (**page 354**) make an assessment of the impact of projected climate change on forest ecosystems in India. The main conclusion using HadRM3 climate outputs is that under the climate projection for the year 2085, 77% and 68% of the forested grids in India are likely to experience shift in forest types under the A2 (with increasing population, inequity, technological change more fragmented and the heterogeneous world) and B2 (with moderate population growth and economic development, environmental protection and social equity) scenario, respectively, with adverse implications for biodiversity. Increasing atmospheric CO_2 concentration and climate warming could also result in a doubling of net primary productivity under the A2 scenario and nearly 70% increase under the B2 scenario.

Simulation results of a regional climate model, HadRM2, were analysed for the northern Indian Ocean to provide the future scenarios of the climate change-related occurrence of tropical cyclones in the Bay of Bengal for the period 2041–60 by Unnikrishan *et al*. (**page 362**). Further, the results show increase in frequencies of tropical cyclones in the Bay, particularly intense events during the post-monsoon period, for the increased GHG run. The frequency of high surges is found to be higher in the GHG model as compared to the control run.

Bhattacharya *et al.* (**page 369**) aim to understand the likely influence of climate change on malaria transmission in India. Applying the malaria transmission window criteria under the future climate change conditions (results of HadRM2) for 2050s, it is projected that malaria is likely to persist in Orissa, West Bengal and southern parts of Assam, bordering north of West Bengal. However, it may shift from the central Indian region to the South Western coastal states of Maharashtra, Karnataka and Kerala. Also the northern states, including Himachal Pradesh and Arunachal Pradesh, Nagaland, Manipur and Mizoram in the northeast may become malaria prone. The duration of the transmission windows is likely to widen in northern and western states and shorten in the southern states.

Patwardan (**page 376**) analyses the vulnerability of developing countries to potential impacts of climate change and the options for adaptation, which are rapidly emerging. The study concludes that in order to prioritize, design and implement interventions to adapt to climate change, it is essential to adopt a coherent and consistent set of definitions and frameworks for examining vulnerability, adaptation and adaptive capacity. He uses the context of the coastal impacts of climate change to draw some explicit linkages between the objectives of vulnerability and adaptation assessment and the definitions used in the analysis. He concludes with some thoughts regarding directions for research with regard to vulnerability and adaptation assessment.

Emissions scenarios presented by Shukla (**page 384**) show that India's per capita emission during the century would rank amongst the lowest. However, India's participation in stabilization regime, such as at a 550 ppmv CO_2 concentration level, would induce significant changes in energy and technology-mix and consequent economic burden on India. Stabilization burden would be lower in scenarios where underlying development paths are sustainable. The near-term energy choices, given their path dependence, could deliver sustained development and climate benefits. Aligning development and climate actions, therefore, is advisable and feasible. The regime instruments, the paper concludes, should aim to first support endogenous climate-friendly actions and then to induce climate-centric actions.

Climate change is recognized as one of the dominant global environmental concerns that could cause significant adverse environmental and socio-economic impacts over the coming centuries. The science of climate change has progressed enormously in the past decade at an unprecedented scale, but there are still significant uncertainties, with respect to emissions estimates, climate projections and impact assessments. Some of the key issues for scientific community to address are:

- Reduction of uncertainties that limit the ability to detect, attribute and understand the current climate change and projection of climate changes, particularly at the regional level.
- Improvement in understanding of the exposure, sensitivity, adaptability and vulnerability of physical, ecological and social systems to climate change at regional and local level.
- Evaluation of climate mitigation options in the context of development, sustainability and equity at regional, national and global level in different sectors.
- Development of sustainable and equitable international protocols, mechanisms and financial arrangements to promote mitigation and adaptation to climate change.

India is a large developing country with nearly two-thirds of the population depending directly on the climate-sensitive sectors such as agriculture, fisheries and forests. The projected climate change under various scenarios is likely to have adverse implications on coastal settlements, food production, freshwater supply, biodiversity and livelihoods. Thus, India has a significant stake in scientific advancement as well as an international understanding to promote mitigation and adaptation to address climate change.

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